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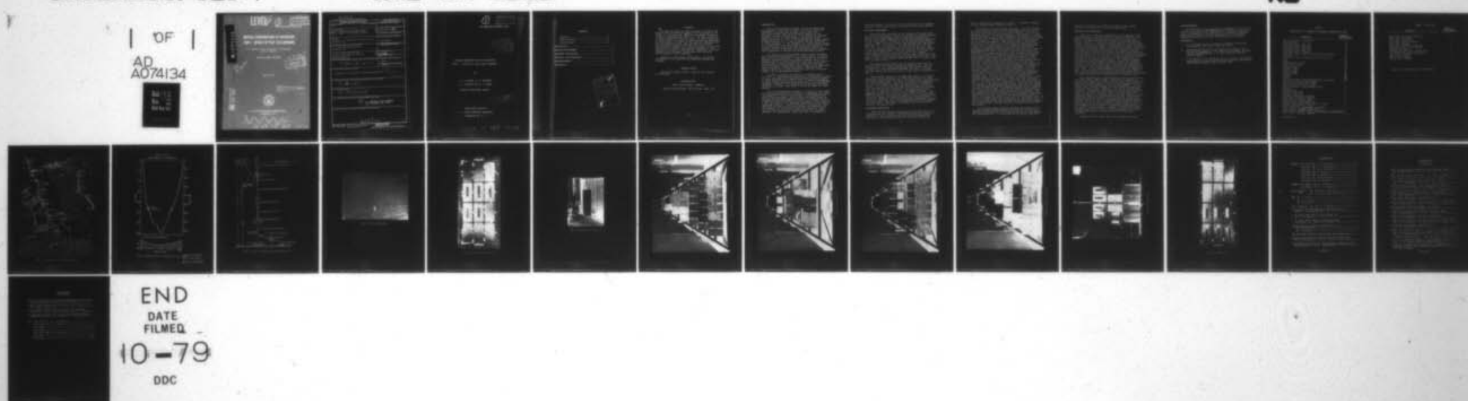

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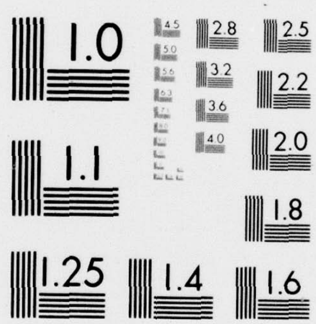
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NRL Memorandum Report 1282

ABYSSAL CORROSION AND ITS MITIGATION
PART I. DETAILS OF PILOT TEST EXPOSURE

L. J. Waldron, M. H. Peterson, B. W. Forgeson,
and B. F. Brown

METALLURGY DIVISION

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March 1962

U. S. NAVAL RESEARCH LABORATORY
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NRL MEMORANDUM REPORT 1282

"ABYSSAL CORROSION AND ITS MITIGATION. PART I. DETAILS OF PILOT TEST EXPOSURE"

BY

L. J. WALDRON, M. H. PETERSON
B. W. FORGESON AND B. F. BROWN
PHYSICAL METALLURGY BRANCH

METALLURGY DIVISION
U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 25, D. C.

APR 30 1962

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ABSTRACT

In March of 1962, an array on which are mounted 144 metallic and non-metallic samples will be exposed in the Tongue of the Ocean area (TOTO) in the Bahama Islands at a depth of approximately 5500 feet. The main objectives of these studies are two-fold; first, to obtain long term corrosion data on a number of basic engineering materials at great depths, so that this data may be correlated with the voluminous corrosion data available for similar materials when exposed at or near the surface of the ocean, and second, to evaluate the various components of the complete test system. Additionally, methods of corrosion mitigation are included to determine their relative effectiveness at these depths.

Details of the exposure environment, the various components of the array and the materials exposed are included.

PROBLEM STATUS

This is an interim report. Work on this problem is continuing.

AUTHORIZATION

NRL Problem Number: 63M04-02

Bureau Problem Number: SF 001-03-07, Task 1515

INTRODUCTION

Over two decades ago a number of metal producers and users agreed on the need for basic data on the corrosion resistance of metals when exposed in sea water and initiated various long-term systematic studies of the corrosion of metals in sea water. The large-scale exposure program of the U. S. Naval Research Laboratory in the Panama Canal Zone (1) and of the International Nickel Company at Harbor Island, N. C., were probably the most extensive of these programs. It was necessary to conduct these studies in a natural sea water environment since any laboratory tests in which synthetic sea water was used would exclude the important effect of marine fouling and would make it practically impossible to maintain an uncontaminated corrodent.

The results of these programs have provided extensive data on the corrosion behavior of a large variety of metals and alloys when exposed at or near the surface of the ocean. However, the marine biology at depths greater than a few hundred feet is so vastly different from that at the surface as to present a valid argument for conducting corrosion studies at great depths rather than relying on the experience near the surface. Different pressure, temperature, and oxygen conditions at great depths may also alter corrosion behavior in an unpredictable manner.

In 1961, a proposal was made by the TRIDENT Office for the U. S. Naval Research Laboratory to undertake a program to study the behavior of engineering materials when exposed at great depths in the ocean in order to develop information on which to base materials specifications for various TRIDENT "hardware" projects. The present report details conditions pertinent to a pilot test which is the first phase of these studies.

It is not considered necessary to include in these deep-sea tests anything like the diversity of specimens and length of exposure that have been specified in the Panama and the Harbor Island programs. It is rather considered adequate, in terms of practical TRIDENT interests, to expose only the standard structural metals and alloys, and for only a year or a very few years, to be reasonably confident of the corrosion technology involved. Several additional vehicles are being assembled for special metals and alloys and especially for the exposure of a variety of bimetallic couples to ensure that we know the practical galvanic series for the high-pressure, low temperature, plant-life free environment of

the ocean depths. The reason for the multiplicity of exposure vehicles is the uncertainty of retrieval of any given vehicle.

EXPOSURE ENVIRONMENT

There are many locations in the oceans of the world that are of sufficient depth in which to perform the proposed studies, but none lend themselves quite as conveniently as does the Tongue of the Ocean (TOTO) area located approximately 200 miles off the east coast of Florida in the British-governed Bahama Islands. TOTO is an area that is approximately bounded between longitude 76° - 30' and 78° - 00' and latitude 23° - 20' and 25° - 00'. It is bordered on the west by the 100 mile long island of Andros and on the south and east by the shoal waters of the Great Bahama Banks. The only entrance to the area for ocean-going vessels is at the north end of the "Tongue" between Andros and New Providence Islands and is about 20 miles wide. TOTO is 20 to 25 miles in width and 125 miles long. The depth of water varies between 4200 and 6000 feet. A map of the area is shown in Fig. 1.

The specific area chosen for the present pilot test is located 3 miles off Andros Island at longitude 77° - 50' and latitude 24° - 55', between Saddleback Cay and Goulding Cay in water that is between 5000 and 6000 feet deep. A cross-section showing the bottom contour in this area is presented in Fig. 2.

Hydrographic studies in the TOTO area made by the Marine Laboratory of the University of Miami (2) for the U. S. Navy Underwater Ordnance Station state, "The TOTO can be characterized as a small model-ocean. The depth is great for an embayment and the water structure, except at the surface, is entirely oceanic. It differs from the open ocean in that the circulation is sluggish, the current speed is very small and the surface water is slightly modified". Salinities range from 35.1 o/oo at 2600 feet to 34.9 o/oo at 8500-foot depth. The temperatures range from 6.0 to 6.5°C at 3300 feet to 3.3°C at 8500-foot depth. The dissolved oxygen in ml/l is approximately 4.5 at the surface and approximately 5.5 at depths around 4300 feet. However, there are considerable variations reported in this property and many of the measured values fall outside of these limits. The bottom throughout most of the area of TOTO is a calcareous ooze.

EQUIPMENT DESCRIPTION

Since one of the main objectives of this pilot test is to determine the best method of exposing materials at depths of 6000 feet in such a manner that they can be retrieved for evaluation, the primary requisite of the array design was

ease of handling and lightness in weight. A schematic diagram of the complete array is shown in Fig. 3.

The vertically floating spar buoy, Fig. 4, at the surface, is constructed of glass-reinforced polyester resin and filled with rigid urethane foam so as to be unsinkable. The buoy is equipped with a white light mounted at a focal plane of 7 feet above the surface. This light flashes at intervals of 5 seconds during hours of darkness and is visible for a distance of 3 miles in clear weather. The auxiliary surface buoy is also plastic and 11 inches in diameter. This buoy is used to facilitate retrieval of the array without disturbing the main spar buoy. A rack, Fig. 5, containing a total of twelve exposure panels of steel is attached directly to the 50 feet of 3/8-inch galvanized chain immediately beneath the spar buoy at a depth of approximately 40 feet. The surface section of the array is attached to an underwater buoyancy cell located 75 feet above the ocean bottom with a 6000 foot length of 5/8-inch diameter black polypropylene rope with a breaking strength of about 6500 pounds. The underwater buoyancy cell, Fig. 6, is constructed of aluminum and consists of 4 two-foot diameter balls with 3/4-inch shell thickness contained in a 9 foot long cylinder. This cell has a positive buoyancy of 475 pounds and will support the main specimen vehicle immediately beneath it with a net buoyancy of approximately 130 pounds. The main specimen vehicle is attached to the underwater cell by a 10-foot section of 1/2-inch galvanized chain and supported at a distance of 50 feet off the ocean bottom by the underwater buoyancy cell. The main test vehicle is constructed of aluminum angle, and with the rack that is mounted in its center, contains 120 exposure specimens. Sides one, two, three and four of the main test vehicle and the center rack are shown in Figs. 7, 8, 9, 10, and 11, respectively. The main test vehicle is attached to the 200-pound Navy anchor with a 50 foot length of 7/16-inch diameter black polypropylene rope with a breaking strength of 3100 pounds. The smaller diameter rope is used in this location as a safety link in the array in the event that the anchors foul on the bottom and become irretrievable. The main 200-pound anchor is attached to an auxiliary 35 pound plow anchor with a 60 foot length of 1/2-inch galvanized chain to which is attached the bottom rack, Fig. 12. The bottom rack will lie on the ocean bottom and is identical to the surface rack with the exception that the stainless steel panels are excluded, and in their place collector panels of transite and wood have been added.

The foregoing design permits dropping and retrieval with reduced handling problem compared with the use of wire rope and puts minimal stress on the long section of the rope during the exposure period. It also keeps the principal experiment

well off the ocean floor where ooze might create special corrosion conditions of only local significance.

MATERIALS AND PROCEDURES

Since one of the prime requisites in the design of the array has been to keep the weight as light as possible, only the basic metals and materials are included in this drop. Each of the materials has been exposed in duplicate and are listed in Table 1. Nominally the samples are 1/16-inch thick, 6"x12". The plastic and non-metallic samples are of varying thickness and 12-inch square. Additionally a number of cathodically protected steel panels are included since the results of a limited preliminary investigation (3) indicated that the requirements for cathodically protecting steel were different at great depths than at the surface. The stainless steel panels with the "built-in" crevice were included to ascertain whether the absence of crevice corrosion at great depths noted in reference 3 had general significance. All samples intended for exposure were thoroughly cleaned, weighed, and thickness measured. The steel panels were exposed in two conditions. In the first condition the back of the panel is protected with two coats of zinc chromate primer and one 5-mil thickness of vinyl tape. In the second condition the panels are completely bare. The protection of the back of the panel facilitates and makes more accurate the post exposure evaluation of pitting. All metallic samples are insulated from the aluminum rack.

The scheduled date of installation of this first drop is the latter part of March 1962. Schedules are arranged to retrieve and inspect the complete array after three, six, nine, and twelve months' exposure. During these inspections each panel will be thoroughly examined and photographed. If it is evident that corrosion damage of a given panel is sufficient to warrant quantitative evaluation, it will be removed from exposure. In addition, there have been sufficient samples of plain carbon steel, with and without one side coated, to allow the removal of duplicate panels of this material at each inspection period for quantitative evaluation. When these panels are removed they will be replaced with identical uncorroded panels in order to calibrate the successive exposure periods. If at any of the scheduled inspections the test array appears to be deteriorated to such an extent that it is not thought likely to survive an additional exposure period, the test will be terminated. However, as long as the array equipment survives, it will be left in exposure until each of the materials exposed exhibits sufficient attack to be evaluated.

Reports will be issued after each inspection period.

ACKNOWLEDGMENTS

This project is being supported by TRIDENT, Mr.L.M. Treitel, with Mr. F.E. Cook as the BUSHIPS project engineer. Appreciation is expressed for the cooperation of the Navy Hydrographic Office and the Office of Naval Research, and to the various companies and agencies who have contributed to the program.

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1. A. L. Alexander et al, "Corrosion of Metals in Tropical Environments", NRL Report 4929, June 1957.

2. "Oceanographic Survey of the Tongue of the Ocean", Vol. 1. The Marine Laboratory of the University of Miami, Contract Number N140(122)65617B, U. S. Navy Underwater Ordnance Station (1958).

3. L. J. Waldron, M. H. Peterson, and B. F. Brown, "Preliminary Experiments in Deep Sea Corrosion and Corrosion Prevention", NRL Memorandum Report 1242, November 1961.

TABLE 1

MATERIALS TO BE EXPOSED TO ABYSSAL CORROSION IN TOTO

MATERIAL	NUMERICAL DESIGNATION*
Low carbon steel, AISI 1010	1
Steel, HY-80	2
Stainless steel, type 304	3
Stainless steel, type 316	4
Stainless steel, type 410	5
Stainless steel, type 430	6
Stainless steel, Tenelon	7
Stainless steel, type 410 with built-in crevice	8
Titanium	9
Galvanized steel continuous run, 2 oz per ft	12
Zinc	13
Monel	14
Copper-Nickel, 90-10	15
Naval brass, 60-40	16
Phosphor bronze	17
Aluminum 1100	18
Aluminum 5086	19
Aluminum 6061	23
Aluminum 7079	24
Inconel	25
Copper	26
Stainless steel, type 316 with built-in crevice	27
Grey vinyl coating, Mil-P 15934	—
Anti-fouling F121, Mil-P 15931	—
Anti-fouling Dolfinite, X-1265	—
Special acrylic, anti-fouling, M-559	—
Urethane	—
Devran epoxy	—
Neoprene, ML-C-589	—
Neoprene, ML-C-619	—
Filament wound epoxy laminate	—
Reinforced polyester laminate	—
High density urethane foam	—
Syntactic foam (microballoons)	—
Rubber sheet, MIL-R-15058, type 3, class 1	—
O-Rings, MIL-P-5516, class B	—
Wood, Angelique - *Dicorynea paraensis*	—
Wood, Balsa - *Ochroma lagopus*	—
Wood, Alaskan Yellow Cedar - *Chamaecyparis nootkatensis*	—
Wood, Teak - *Tectona grandis*	—

(continued)

TABLE 1 (continued)

MATERIAL	NUMERICAL DESIGNATION*
Hastalloy, N cladding sections	–
Wire rope, insulated	–
Wire rope, zinc coated	–
Wire rope, aluminum coated	–
Wire rope, Tenelon	–
Wire rope, stainless, type 304	–
Compressed wood, resin treated	–
Transite and wood	–
Low carbon steel with aluminum anode	–
Low carbon steel with zinc anode	–
Nylon rope, twisted	–
Nylon rope, braided	–
Dacron rope, twisted	–

* Used for identification of the material.

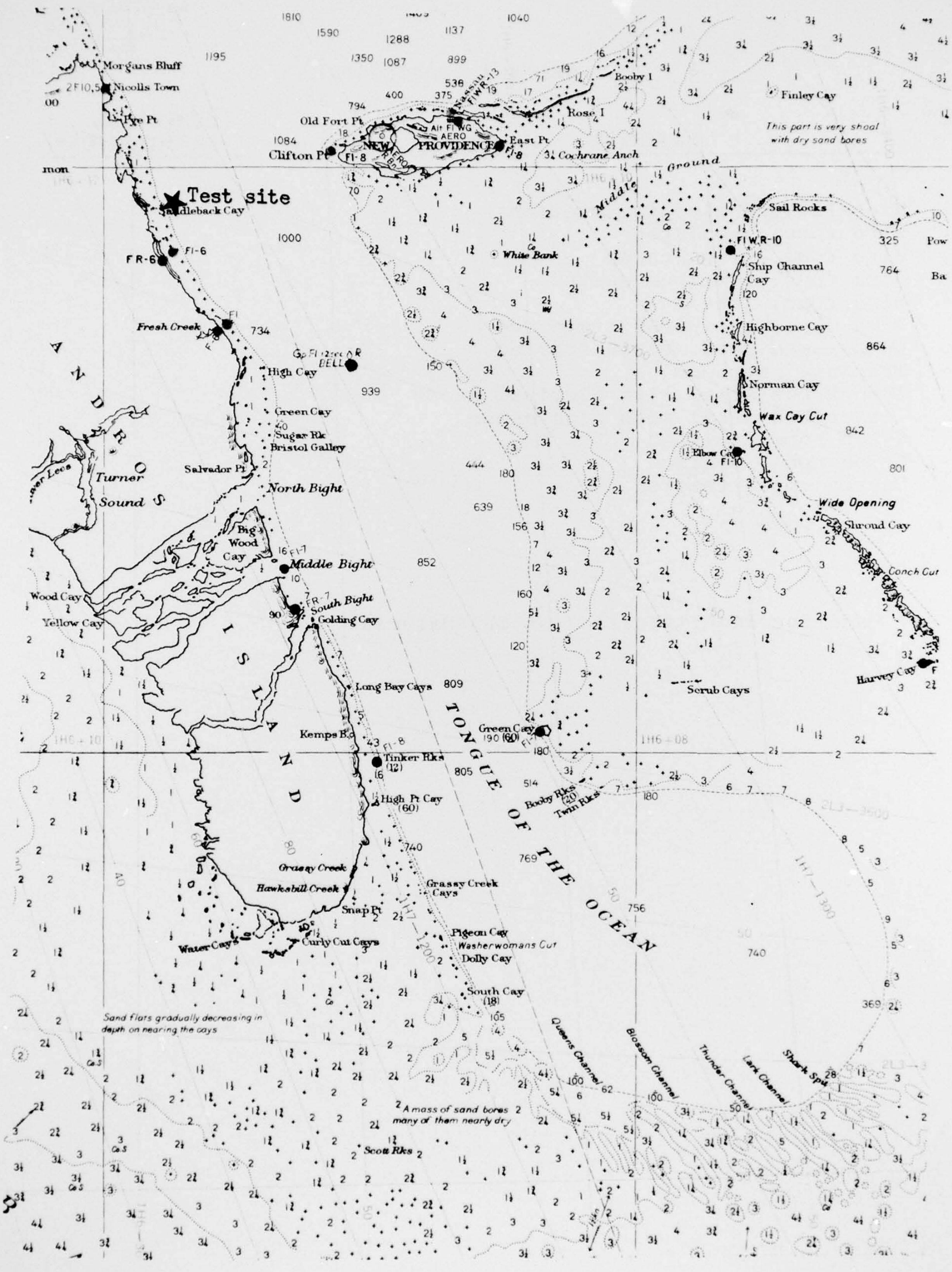

Fig. 1 - Tongue of the ocean, Bahama Islands

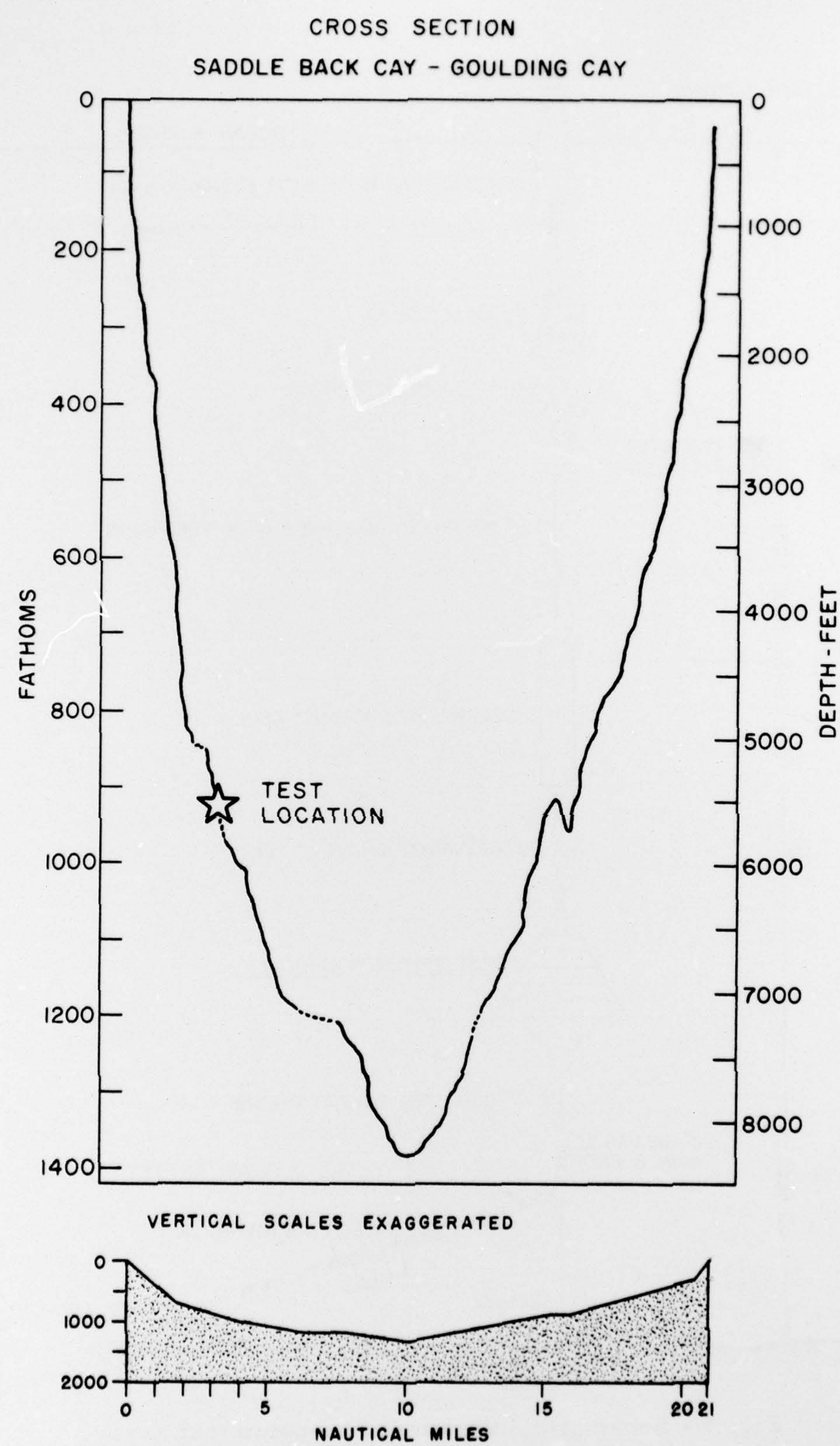

Fig. 2 - Saddleback Cay - Goulding Cay cross section

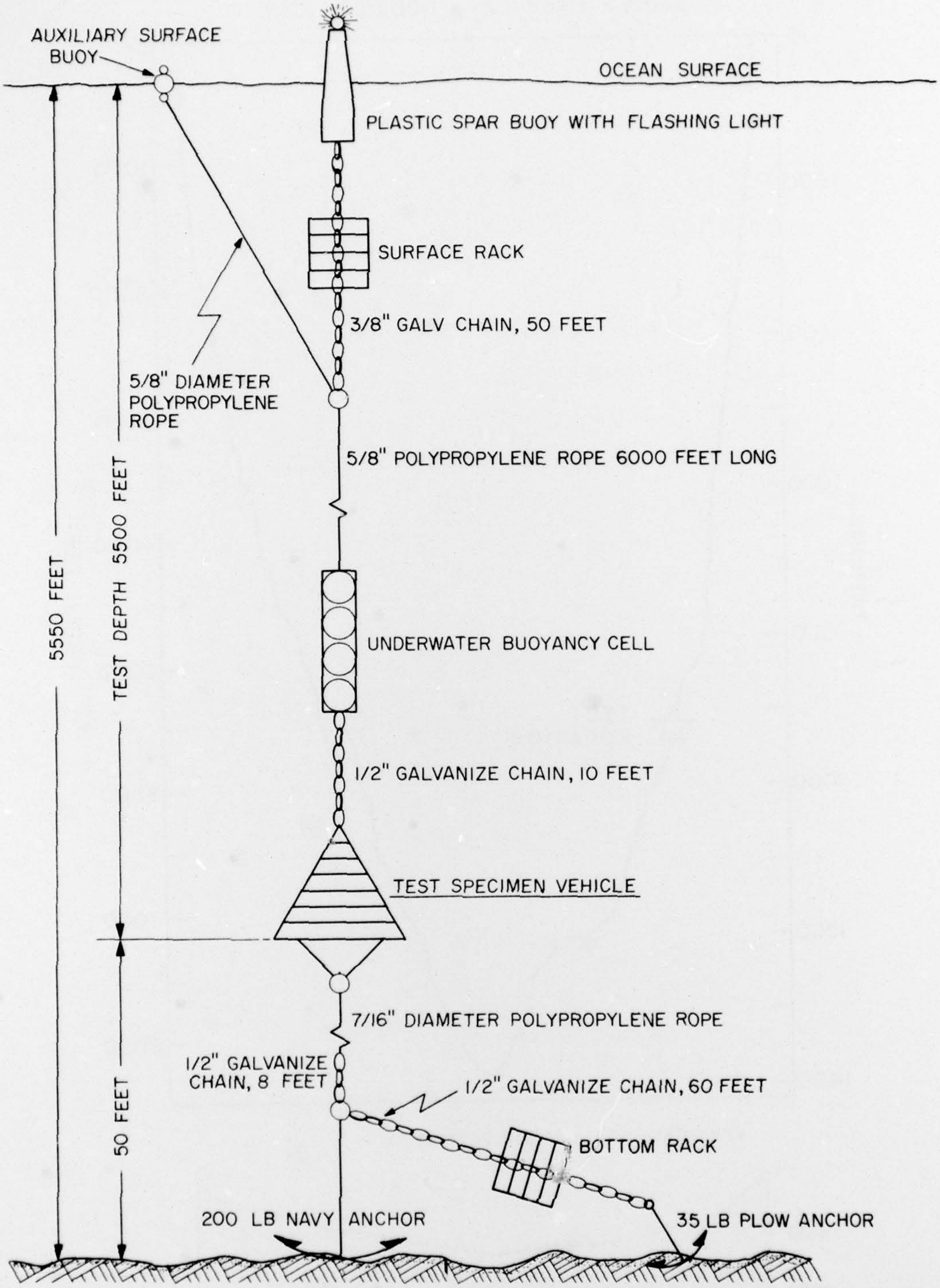

Fig. 3 - Schematic diagram of corrosion test array

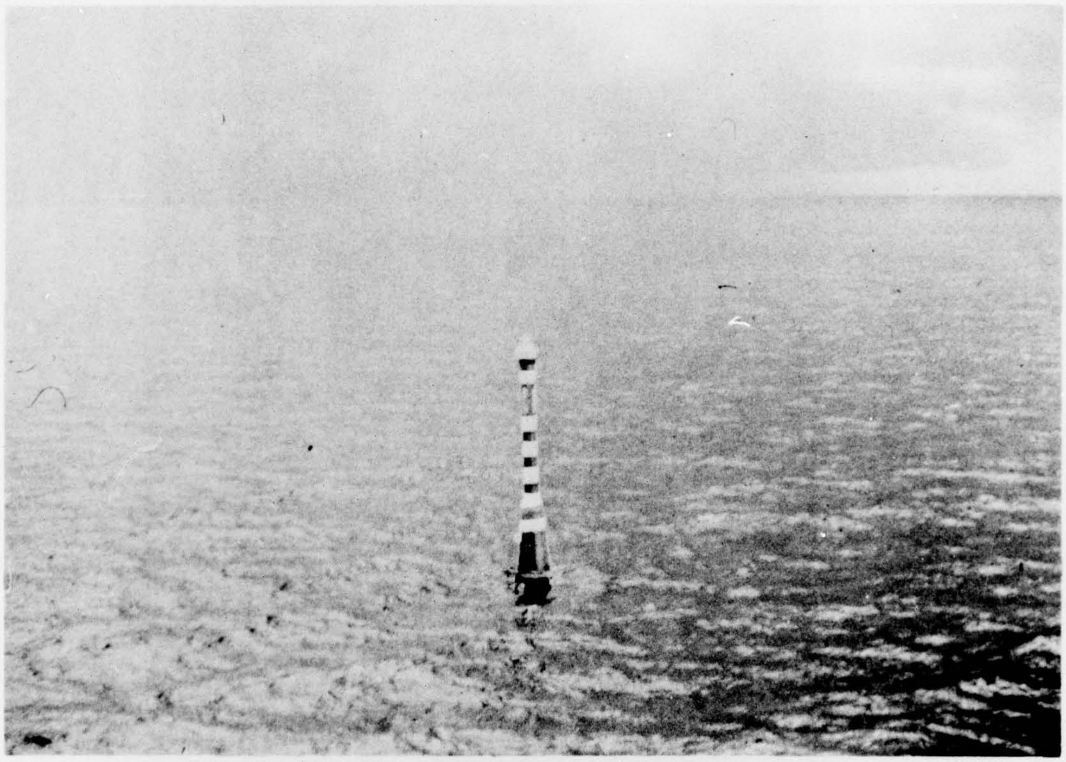

Fig. 4 - Surface Spar Buoy

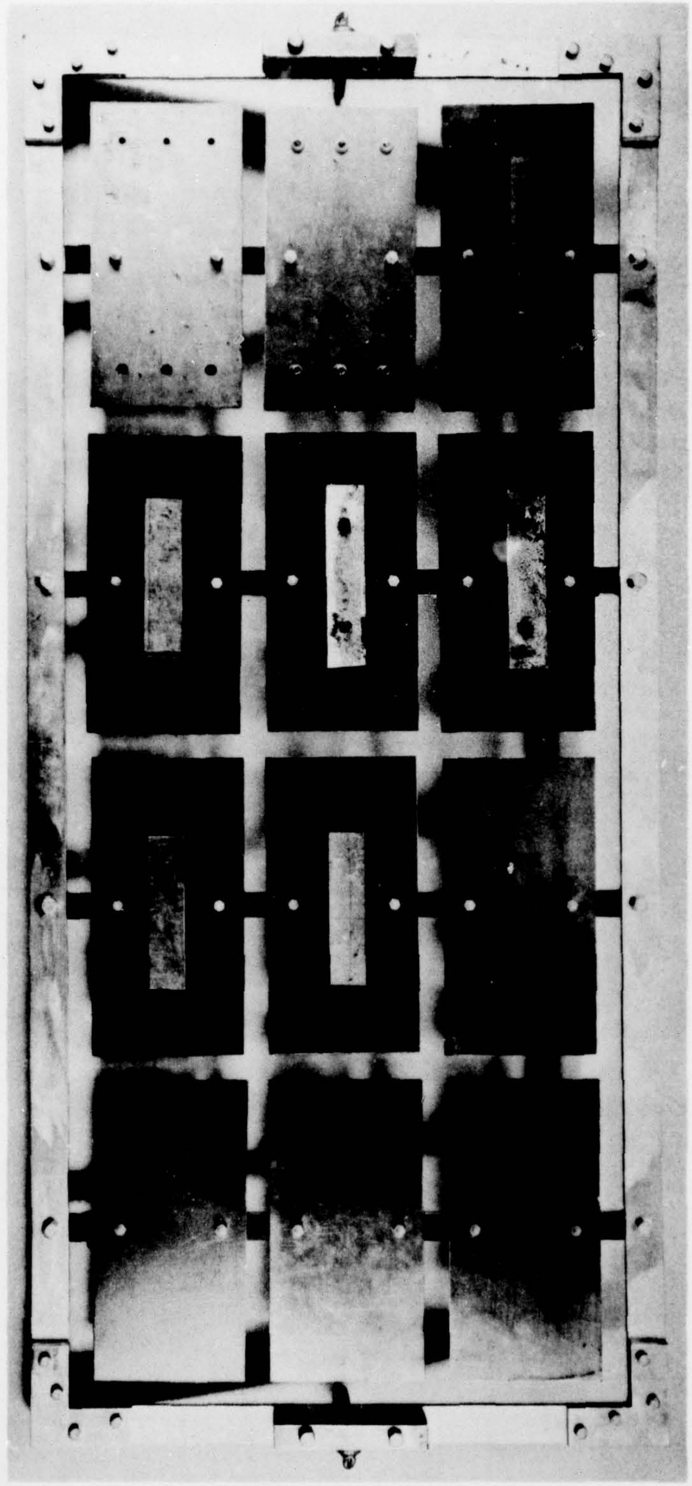

Fig. 5 - Surface Exposure Rack.

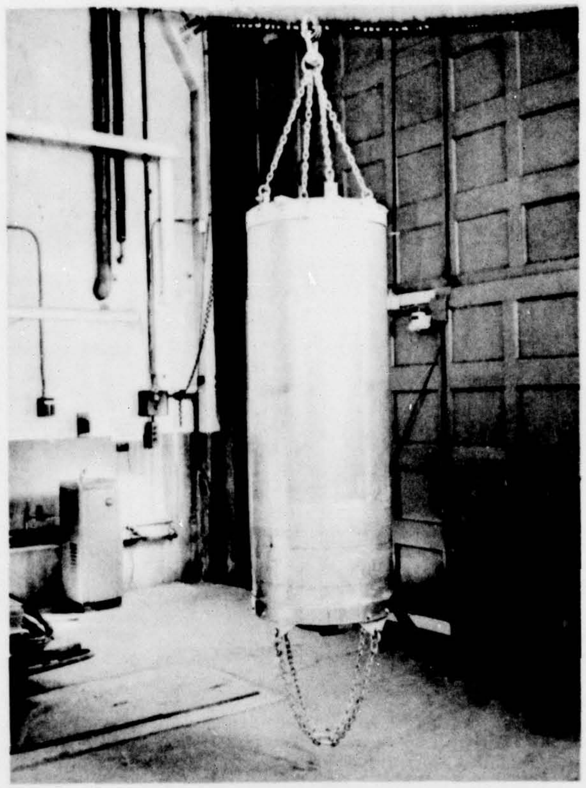

Fig. 6 - Underwater buoyancy cell

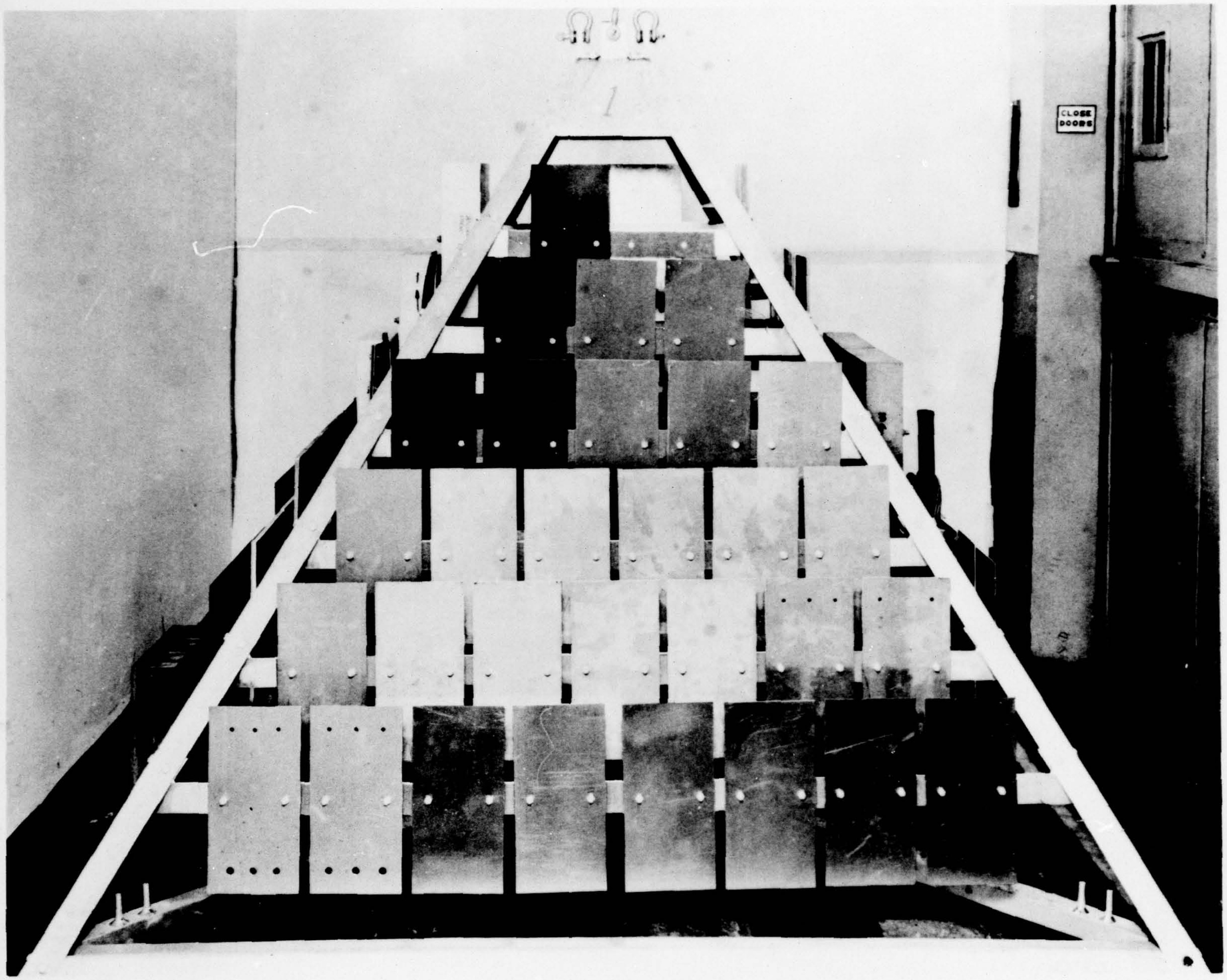

Fig. 7 - Main rack, side one

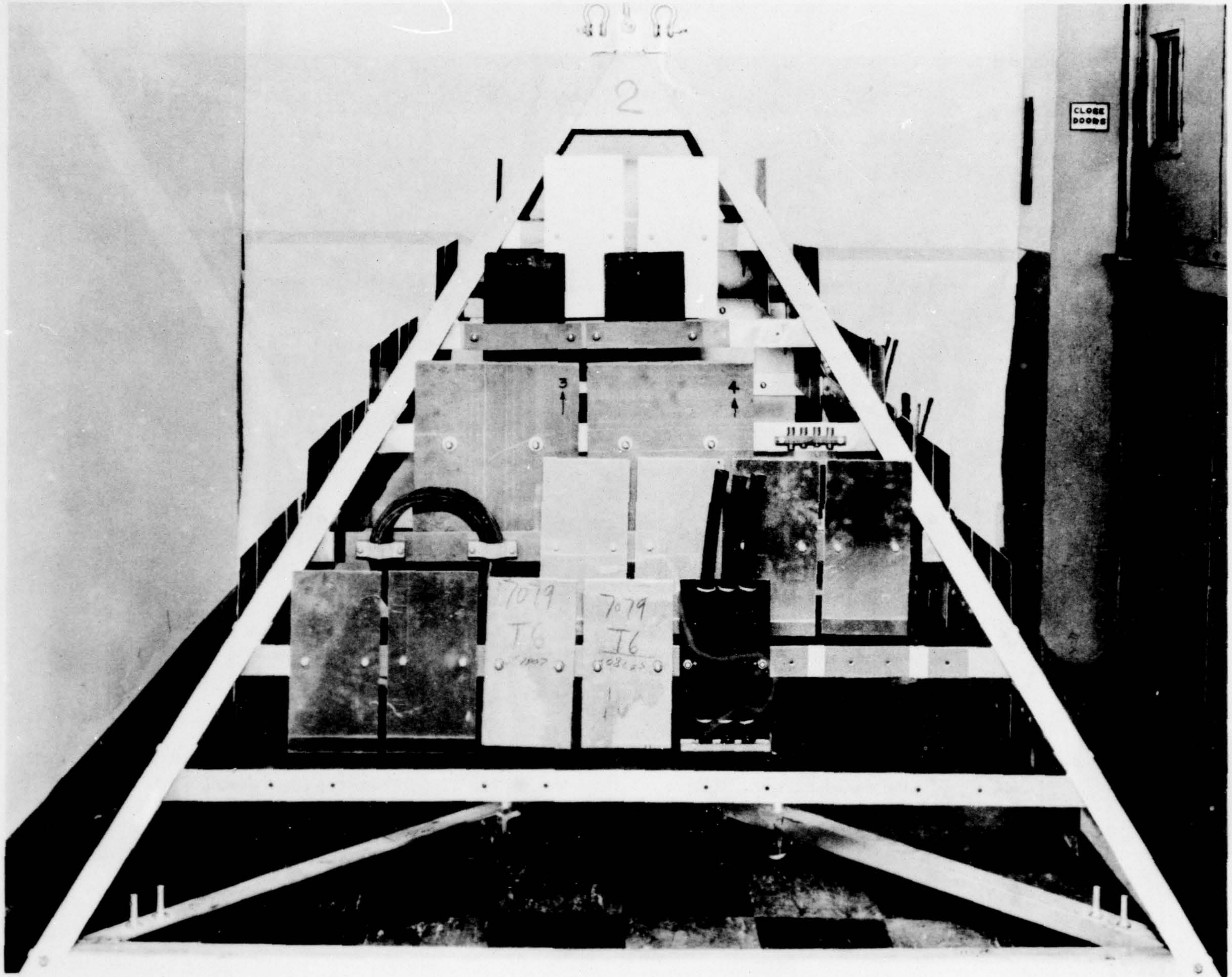

Fig. 8 - Main rack, side two

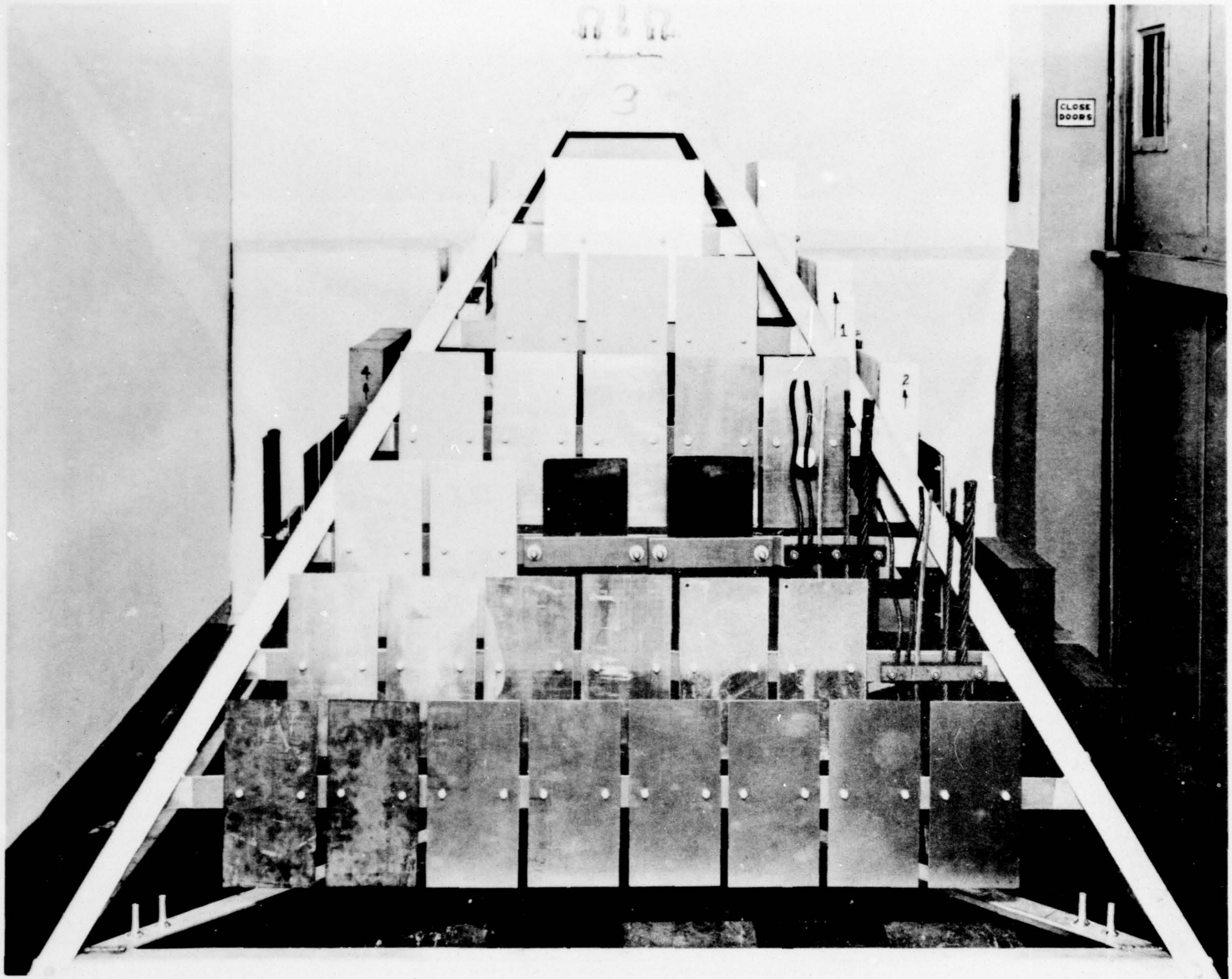

Fig. 9 - Main rack, side three

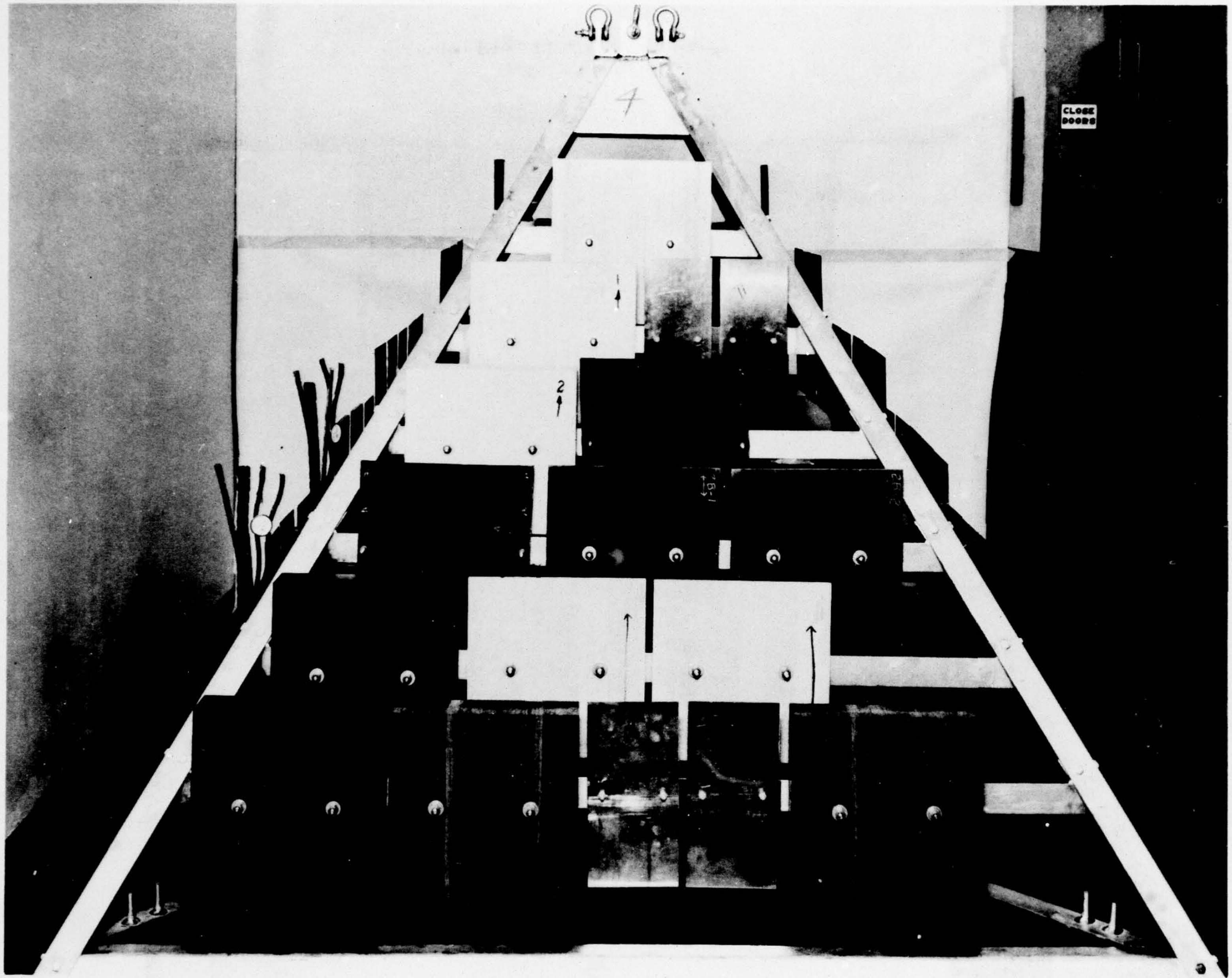

Fig. 10 - Main rack, side four

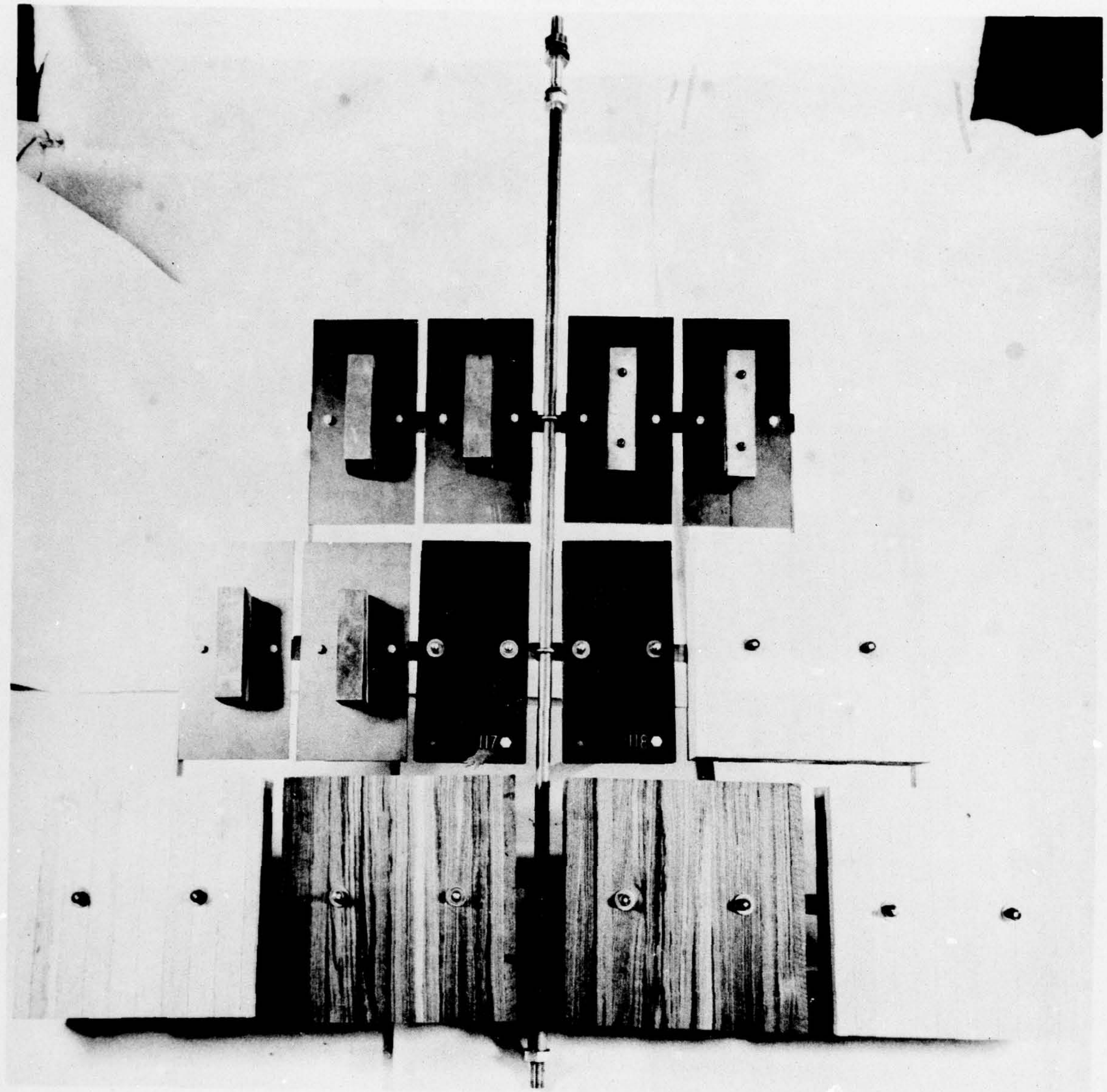

Fig. 11 - Center rack

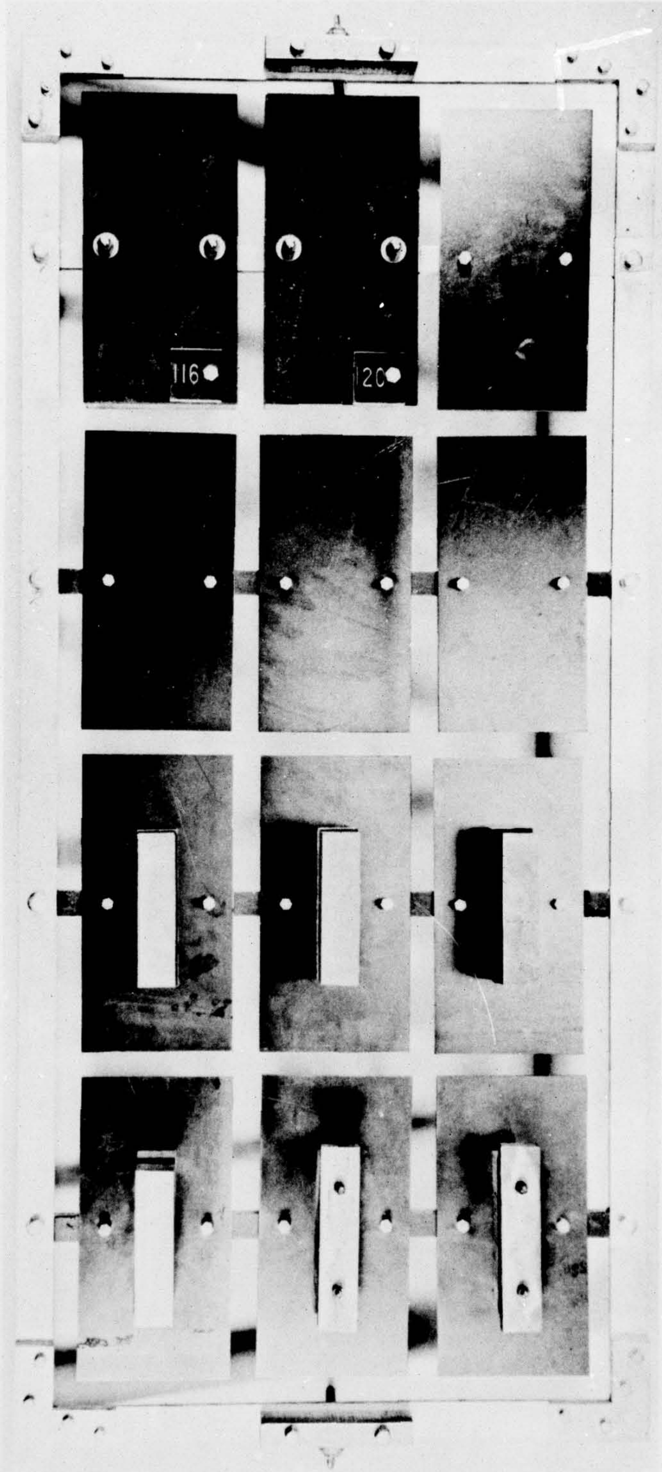

Fig. 12 - Bottom rack

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